MOTION COORDINATION OF MULTI-AGENT SYSTEMS: THEORY AND EXPERIMENTS

By

He Bai

An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: ELECTRICAL ENGINEERING

The original of the complete thesis is on file
in the Rensselaer Polytechnic Institute Library

Examining Committee:

Dr. Murat Arcak, Thesis Adviser

Dr. John T. Wen, Thesis Adviser

Dr. Joe H. Chow, Member

Dr. Arthur Sanderson, Member

Dr. B. Wayne Bequette, Member

Rensselaer Polytechnic Institute
Troy, New York

July 2009
(For Graduation August 2009)

ABSTRACT

Recent years have witnessed an increasing research and applications in motion coordination of multiple agent systems, such as mobile sensor networks, cooperative robotics and vehicles. A major challenge of these problems is to use local information to achieve a prescribed group behavior. Motion coordination finds its natural applications in schooling and flocking in biological organisms and distributed robots, formation control of spacecrafts, sensor coverage optimization, distributed computing, *etc*.

In this thesis, we build on a passivity based framework and study several motion coordination problems with bidirectional information flows between agents. We first review the passivity based approach and apply it to the formation control problem. The resulting feedback laws only make use of local information and thus can be implemented in a decentralized fashion. We then extend it to the situation where only the leader has the desired velocity. In this case, we propose adaptive redesigns with which that the rest of the agents estimate the desired velocity information and recover the nonadaptive design results. These formation control techniques are further validated using two robots, each equipped with a camera as the only sensor measuring the relative position between them. We also apply our designs to a load transport problem, where the agents move a flexible load with a desired constant velocity and regulate the contact forces on the load.

We next examine the robustness of the motion coordination system against switching topology, link gain variation, and unmodeled dynamics. For each case, we illustrate with examples possible instability mechanisms and discuss the conditions under which the stability is maintained. We also demonstrate the instability mechanism "conformation change" in the context of gradient climbing of a field with multiple equilibria. Numerical examples show that the coordinated agents will jump between the minima collectively.

Another major research lies in the coordination of the attitudes of multiple rigid bodies. Under the relaxed assumption that the agents only have relative atti-

tude information, we develop a passivity-based control that guarantees the synchronization of the attitudes. Combining this attitude control and previous formation control techniques, we achieve the $SE(3)$ formation, where the agents move as a rigid body along the trajectory.